Brain^3 Spatialized Sonification
Technical Documentation

Carles Tardío Pi, SPECS - Universitat Pompeu Fabra

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1 Introduction

In this project, we have developed a system for a 3D audio spatialized sonification of Hagmann connectome dataset within the Brain^3 application[1]. In this regard, the system can be divided in two main parts: the parameter based sonification[2] of anatomical connectivity data and the sound spatialization of the already sonified data. In the figure above, we can see an overall schema of the system.

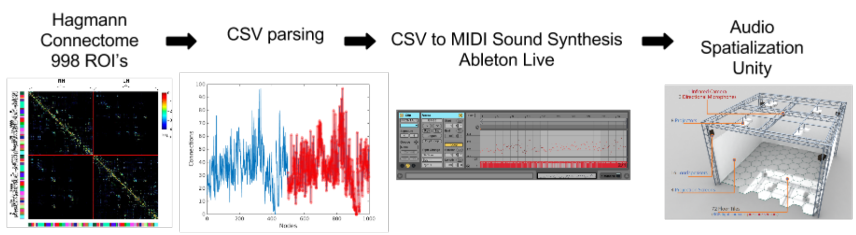

Figure 1: Overall Design Schema

Hagmann dataset[3] is a comprehensive map of neural connections in the brain. The dataset is composed of 998 regions of interest (ROIs), 28000 unidirectional connections and 66 anatomical subregions in the left and right hemisphere of the human brain. For our purpose, we have clustered those subregions into Frontal, Parietal, Occipital, Cingulate and Temporal regions, both for left and right.

Once anatomical connectivity data is grouped, we create a csv file containing the nodes of every region together with the number of connections for every node and an average connectivity weight of every region. Later on, we export export csv data into a midi file. This step can be achieved by two different methods: using the Sonification Sanbox[4]
`http://sonify.psych.gatech.edu/research/sonification_sandbox/`

or a miditocsv script
`http://www.fourmilab.ch/webtools/midicsv/#midicsv.1`
We explain the mappings from data to sound in section 2.

Once we have a midi file, we synthesize it to an audio output using Ableton for Live, as we explain in section 3. After that, sounds are embedded into Unity software in order to be spacialized for the Brain^2 application running on the XIM environment.

2 CSV to MIDI

Since the midi to csv only runs within windows 32-bit platform we will be using Sonification Sandbox java application. We have followed the next steps in order to generate our midi file from csv:

- Import CSV containing neuron ID and number of connections per neuron.
- We enable Pitch mapping.
- Check polarity is positive.
- Set minimum note on 56 (Ab) and maximum note on 113 (F).
- Export as .mid

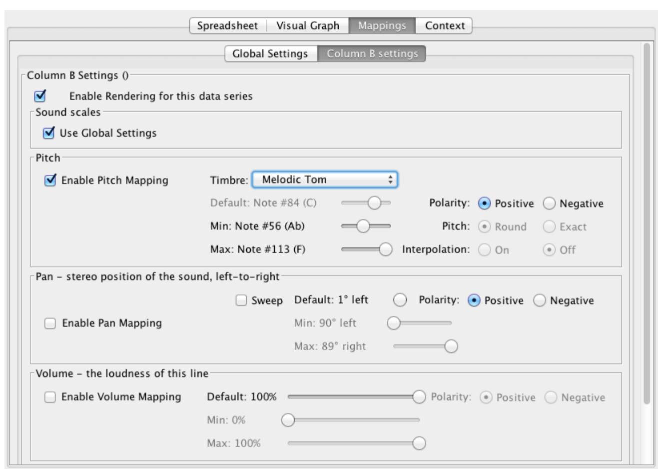

Figure 2: Sonification Sandbox Mappings Window

In a second step, we map the average weight connectivity of a particular region to the midi velocity, i.e. volume of the track. The mapping is done by a linear interpolation where the weight extreme values are 0.0135 and 0.0501, and the midi velocity extreme values range from 64 to 127.

In a final instance, what we have is a mapping according to:

- Number of connections per node → Pitch of the note.
- Average weight connectivity of a region → Midi Velocity.

Moreover, different sonification schemas with different mappings can be applied. It is possible to order the nodes from less connected to the more connected ones. In that sense, the audio representation curve that will be generated can give us account of the homogeneity of connections within a region, see figure below.

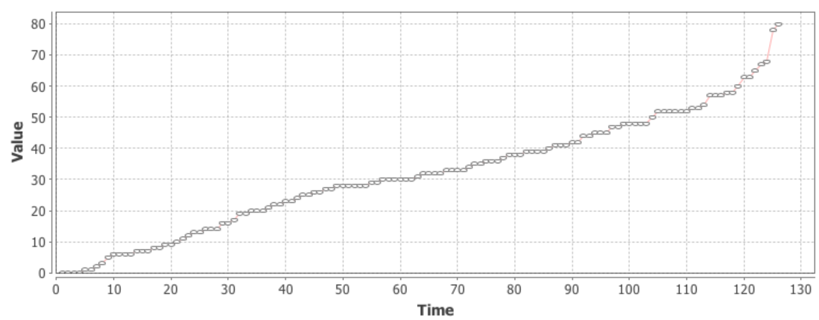

Figure 3: In x-axis, nodes ordered from - to + conns for the temporal brain area

3 Sound Synthesis

MIDI sound synthesis is mainly achieved by using 2 virtual synthesizers (VST's): Arturia Analog Laboratory `http://www.arturia.com/products/analog-classics/analoglab` and NI Massive `http://www.native-instruments.com/es/products/komplete/synths/massive/`.

Timbre sound choices and spatial distribution of every cortical region is mapped to an orchestra ensemble distribution.In this regard, we have the following sections:

- Wind section → Right parietal cortex.
- Brass section → Right temporal cortex.
- String section → Left and right frontal cortex.
- Percusion section → Left and right occipital, l and r cingulate cortex.
- Keybord section → Left parietal cortex and left temporal cortex.

4 Spatialization

Audio source location and therefore spatial placement is done through Unity sound engine. Audio .wav archives exported from Ableton Live are placed in the Region Colliders. An CS script is done in order to be able to select that area while connecting it to sound output.

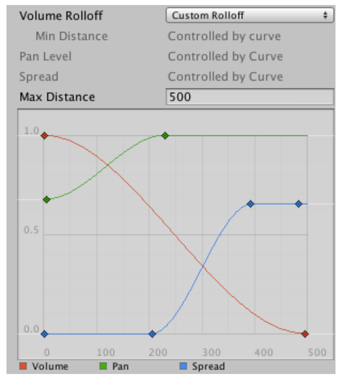

Figure 4: Unity Audio Panel

References

[1] Alberto Betella, Ryszard Cetnarski, Riccardo Zucca, Xerxes D Arsiwalla, Enrique Martínez, Pedro Omedas, Anna Mura, and Paul FMJ Verschure. Brainx 3: embodied exploration of neural data. In *Proceedings of the 2014 Virtual Reality International Conference*, page 37. ACM, 2014.

[2] Thomas Hermann and Helge Ritter. Listen to your data: Model-based sonification for data analysis. *Advances in intelligent computing and multimedia systems*, 8:189–194, 1999.

[3] Olaf Sporns, Giulio Tononi, and Rolf Kötter. The human connectome: a structural description of the human brain. *PLoS computational biology*, 1(4):e42, 2005.

[4] Bruce N Walker and Joshua T Cothran. Sonification sandbox: A graphical toolkit for auditory graphs. 2003.